Field Test Program for Long-Term Operation of a COHPAC® System for Removing Mercury from Coal-Fired Flue Gas

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DISCLAIMER

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ABSTRACT

With the Nation's coal-burning utilities facing the possibility of tighter controls on mercury pollutants, the U.S. Department of Energy is funding projects that could offer power plant operators better ways to reduce these emissions at much lower costs. Sorbent injection technology represents one of the simplest and most mature approaches to controlling mercury emissions from coal-fired boilers. It involves injecting a solid material such as powdered activated carbon into the flue gas. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface. The sorbent with the mercury attached is then collected by the existing particle control device along with the other solid material, primarily fly ash.

During 2001, ADA Environmental Solutions (ADA-ES) conducted a full-scale demonstration of sorbent-based mercury control technology at the Alabama Power E.C. Gaston Station (Wilsonville, Alabama). This unit burns a low-sulfur bituminous coal and uses a hot-side electrostatic precipitator (ESP) in combination with a Compact Hybrid Particulate Collector (COHPAC®) baghouse to collect fly ash. The majority of the fly ash is collected in the ESP with the residual being collected in the COHPAC® baghouse. Activated carbon was injected between the ESP and COHPAC® units to collect the mercury.

Short-term mercury removal levels in excess of 90% were achieved using the COHPAC® unit. The test also showed that activated carbon was effective in removing both forms of mercury–elemental and oxidized. However, a great deal of additional testing is required to further characterize the capabilities and limitations of this technology relative to use with baghouse systems such as COHPAC®. It is important to determine performance over an extended period of time to fully assess all operational parameters.

The project described in this report focuses on fully demonstrating sorbent injection technology at a coal-fired power generating plant that is equipped with a COHPAC® system. The overall objective is to evaluate the long-term effects of sorbent injection on mercury capture and COHPAC® performance. The work is being done on one-half of the gas stream at Alabama Power Company's Plant Gaston Unit 3 (nominally 135 MW). Data from the testing will be used to determine:

1. If sorbent injection into a high air-to-cloth ratio baghouse is a viable, long-term approach for mercury control; and
2. Design criteria and costs for new baghouse/sorbent injection systems that will use a similar, polishing baghouse (TOXECON™) approach.

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EXECUTIVE SUMMARY

ADA-ES began work on a Cooperative Agreement with the Department of Energy in September 2002 to fully evaluate Activated Carbon Injection (ACI) in conjunction with a high-ratio baghouse (COHPAC®) for mercury control. The work is being conducted at Alabama Power Company's Plant Gaston. During the two-year project, a powdered ACI system will be installed and tested at the plant for a continuous one-year period. ADA-ES' responsibilities for managing the project include engineering, testing, economic analysis, and information transfer functions.

During the seventh reporting quarter, January through March 2004, progress on the project was made in the following areas (Unit 3 was offline from mid-February until mid-April):

- Received Ontario Hydro results from tests on the original bags.
- Completed baseline tests on new, high-perm bags.
- Began activated carbon tests on high-perm bags.
- Made periodic measurements of hopper ash LOI.
- Prepared for alternative carbon tests.

INTRODUCTION

Cooperative Agreement No. DE-FC26-02NT41591 was awarded to ADA-ES to demonstrate Activated Carbon Injection (ACI) technology on a coal-fired boiler equipped with a COHPAC® baghouse. Under the contract, ADA-ES is working in partnership with DOE/NETL, Alabama Power, and EPRI.

A detailed topical report will be prepared at the end of the test. Quarterly reports will be used to provide project overviews and technology transfer information.

Test Schedule

- Baseline Period 1 (March 28 – April 21)
- Baseline Period 2 (May 28 – June 26)
- Optimization Period 1 (April 21 – May 27)
- Optimization Period 2 (June 26 – July 18)
- Long-Term Test on Original Bags (July 19 – November 25)
- Long-Term Test on High-Perm Bags (December 15 – Present)

Team Members

This program is made possible by significant cost-share support from the following companies:

- Duke Power
- EPRI
- Southern Company and Alabama Power Company
- Hamon Research-Cottrell, Inc.
- Allegheny Power
- Ontario Power Generation
- TVA
- Duke Power
- Arch Coal, Inc.
- ADA-ES, Inc.

A group of highly qualified individuals and companies was assembled to implement this program. Project team members include:

- ADA-ES, Inc.
- Southern Research Institute
- Grubb Filtration Testing Services, Inc.
- Reaction Engineering International

EXPERIMENTAL

Activated Carbon Injection Equipment

The activated carbon injection equipment was installed, field-tested, and continues to operate.

Mercury Analyzer

The mercury analyzer is operating and measuring total vapor-phase mercury at the inlet and outlet of the COHPAC® baghouse.

A full equipment description can be found in DOE Report No. 41591R03.

RESULTS AND DISCUSSION

Significant progress was made during this reporting period to meet the overall objective of demonstrating long-term performance of carbon injection for mercury control. The original test plan was adapted to the current operating conditions at the host site. These changes were documented in Report No. 41591R04, but primarily consisted of extending the baseline and optimization tests and modifying the injection scheme. The test plan for this program has five primary tasks:

1. Design and install an activated carbon injection system capable of continuous operation for up to one year.
2. Install a mercury analyzer capable of long-term, continuous operation. This analyzer is referred to as a Semi-Continuous Emissions Monitor (S-CEM).
3. Evaluate the long-term performance of carbon injection upstream of COHPAC® for mercury control. This task has two separate test periods:
    a. The first test (up to six months) will be conducted using the existing set of bags.
    b. The second test (up to six months) will be conducted on a set of new bags made from advanced fabrics.
4. Perform short-term tests of alternative sorbents.
5. Document test procedures and results, and complete reporting and management requirements.

Tasks 1, 2, and 3a have been completed. This report documents activities from task 3b. Task 5 is in progress. Task 4 is scheduled to occur after Task 3 has ended.

Long-Term Performance Evaluation of Original Bags

Ontario Hydro Test Results

The long-term carbon injection tests on the original bags were completed in November 2003. In October 2003, a set of manual measurements was conducted on the Unit 3B COHPAC® baghouse. These tests included simultaneous inlet and outlet measurements of speciated mercury following the Ontario Hydro method, multiple metals sampling at the outlet and hydrogen chloride sampling at the inlet. During the tests, boiler load was held steady at 270 MW and activated carbon was injected at 0.66 lbs/MMacf (20 lbs/h). Average inlet flue gas temperature was 243°F and the outlet was 240°F.

Table 1 presents a summary of the mercury measurement results from the Ontario Hydro tests. The average inlet concentration was 10.2 $\mu g/Nm^3$, the outlet concentration was 2.0 $\mu g/Nm^3$, for an average mercury removal of 80.4%. Table 1 also shows the range of mercury concentrations measured by the S-CEM for the two-day test period. S-CEM mercury concentrations are presented in this manner because at the time of the Ontario Hydro tests, there were some operational problems with the instrument. Figure 1 shows that there is no data for a period on October 7 and 8. The questionable results during this time were caused by the gold trap slipping out of position and not being fully exposed to the sample gas.

The Ontario Hydro inlet speciation results show nearly 44% (4.5 of 10.2) in the particulate phase. The S-CEM shows concentrations in the same range as the manual measurements. These results again point out the sampling artifact associated with the Ontario Hydro method when measurements are made in high particulate loading locations. The upstream filter removes the particulate, but also provides a site to both scrub and oxidize mercury, which affects the speciation measurement.

At the outlet, the Ontario Hydro measurements were at the upper end of concentrations measured by the S-CEM, 2.0 $\mu g/Nm^3$versus 0.3–2.2 $\mu g/Nm^3$. To try to explain this, a thorough Q/A of the data and an investigation of the operation of the S-CEM were conducted. The findings included:

- Overboard calibrations are conducted daily to assure that mercury is not being scrubbed or that unexpected chemical reactions between the flue gas, wet chemicals and vapor-phase mercury are not occurring. The calibration performed before the Ontario Hydro tests showed good recovery of the mercury spike.
- Onboard calibrations of the mercury analyzer are performed routinely. Again, the calibrations during this period were acceptable.
- The analyzer is set up with a battery of diagnostics, which include measurements of light intensity, temperatures, pressures, oxygen levels, solenoid operation, desorb characteristics, and several other parameters. The diagnostics showed normal operation for all data presented in Figure 1.
- A review of operator logs did not have any noted inconsistencies or unusual operation.

- The Q/A documentation from Ontario Hydro test results was reviewed. Laboratory spike recovery and the sample blank looked good. All field tests were considered valid.

Based on this analysis, there is no obvious reason to discount either measurement. It is interesting to note that the Ontario Hydro results match well with the long-term mercury control performance, as shown in Table 2, and confirms that a nominal injection rate of 0.66 lbs/MMacf results in about 80 to 85% mercury control.

Table 1. Results from Ontario Hydro Tests Across the mg/Nm3Unit 3B COHPAC® with Activated Carbon Injection and Original Bags–October 8 and 9, 2003 (all mercury measurements in (mg/Nm3) and corrected to 3% O2).

	Particulate (μg/Nm3)1	Oxidized (μg/Nm3)	Elemental (μg/Nm3)	Total (μg/Nm3)	S-CEM Comparison
COHPAC® Inlet	**4.5**	**2.5**	**3.1**	**10.2**	***8.7–13.4***
COHPAC® Outlet	**0.6**	**1.3**	**0.3**	**2.0**	***0.6–2.2***
Removal Efficiency	**86.7%**	**48.0%**	**91.0%**	**80.4%**	***83–95%***

1. Normal conditions = 32°F

Table 2. Average weekly inlet and outlet mercury concentrations and mercury removal efficiency for October 2003.

Week Starting	Inlet Mercury ($\mu g/m^3$)	Outlet Mercury ($\mu g/m^3$)	Mercury Removal (%)
10/05/03	15.8	2.2	86
10/12/03	15.8	3.1	80
10/19/03	11.6	1.6	86
10/26/03	15.2	3.5	77
Overall Average	**14.6**	**2.6**	**82.2%**

Residual Drag Measurements on Original Bags

A set of in-situ drag measurements was made by Southern Research Institute on the original bags when the baghouse was taken out of service to replace bags. The drag of the four bag bundles varied between 0.44 and 0.81 inches H_2O/ft/min, with an overall average of 0.62 H_2O/ft/min. In March 2003, before the carbon injection tests, the average drag was 0.36 H_2O/ft/min. This is a significant increase in residual drag over a relatively short period and the highest drag ever measured on the Unit 3 COHPAC® bags. However, inlet loading to the baghouse increased at the same time the carbon injection tests started, resulting in an increase in cleaning frequency of the A-side bags also. In February, drag measurements made in the 3A baghouses showed an average drag of 0.53 H_2O/ft/min. This shows that overall higher inlet mass loading from the hot-side ESPs was the primary cause of significantly higher residual drag, not the activated carbon injection.

Figure 2 illustrates the dramatic change in baghouse performance after the March 2003 outage by showing the pulse frequency for A- and B-side baghouses since new bags were installed in October 2000. This graph also shows operating drag, which was maintained by the higher cleaning frequency.

High-Perm Bag Test (December 15 – February 11)

The new high-permeability (high-perm) bags were installed December 4 through 8, 2003. The primary differences in design are denier (an indication of fiber diameter; 2.5 versus 7.0 denier) and permeability (nominally 30 versus 130 cfm/ft^2 @ 0.5" H_2O).

The tentative schedule for the high-perm bag test is:

- Baseline Tests: December 15–January 5
- Optimization Tests: January 6–February 11
- Long-Term Test: Mid-April–TBD

Figure 3 presents inlet and outlet mercury concentrations, mercury removal efficiency, carbon injection rate, mass loading, and pulse frequency for both the Unit 3B and 3A baghouses from December 15 through February 11. From mid-February until mid-April, Unit 3 was offline for scheduled maintenance activities.

The new bags were evaluated without carbon injection from December 15 until January 5. Figure 3 shows that the cleaning frequency was very low, at less than 1 p/b/h. Prior to changing the bags, the Unit 3B baghouse was often in a continuous clean of 4.4 p/b/h, similar to the cleaning frequency trend for the Unit 3A baghouse in Figure 2.

During this baseline period, with no carbon injection, mercury removal efficiency varied between 0 and 95%. Figure 3 shows that higher mercury removal occurred when inlet mass loading increased.

Activated carbon injection was started on January 5 at a rate of 20 lbs/h (0.66 lbs/MMacf) and was incrementally increased until the outage in February. Because baghouse cleaning frequency was acceptable, it was possible to inject at a constant rate and not reduce injection when inlet mass loading increased. The average mercury removal at each of the four injection conditions shown in Table 3. The average mercury removal was higher in each of these shorter tests than the 85.6% removal that was measured for the four-month carbon injection test with the original bags (during the original bag tests, carbon injection varied with inlet loading). These tests show that there is no difference in mercury removal with the new, high-perm bags when compared to the original bags.

Table 3. Average mercury removal during carbon optimization with high-perm bags.

Injection Rate (lb/h)	Injection Concentration (lbs/MMacf)	RE (%)	Inlet Mass Loading (gr/acf)	Cleaning Frequency (pulses/bag/hour)
20	0.7	87	0.1	0.6
25	0.8	91	0.05	0.7
30	1.0	94	0.06	0.7
35	1.2	93	NA	NA

Bag Inspection and Residual Drag Measurements on High-Perm Bags

During the February outage, Southern Research Institute conducted a bag inspection and drag measurements. Prior to taking the baghouse offline, a fluorescent powder (Visolite^{TM}) was injected into the four compartments on Unit 3 baghouse (two compartments each on A- and B-side). The compartments were then opened and the top of the tubesheet inspected with a black light. Seven failed bags were found in the B-side baghouse and eight bags' locations were found where there was either no bag or the bag had slipped down the cage. All of the missing or failed bags appear to be caused by poor installation. New, high-perm bags were used to replace the failed and missing bags.

The average drag of the high-perm bags after less than three months of operation was 0.11 H_2O/ft/min. This low value is typical for a new bag.

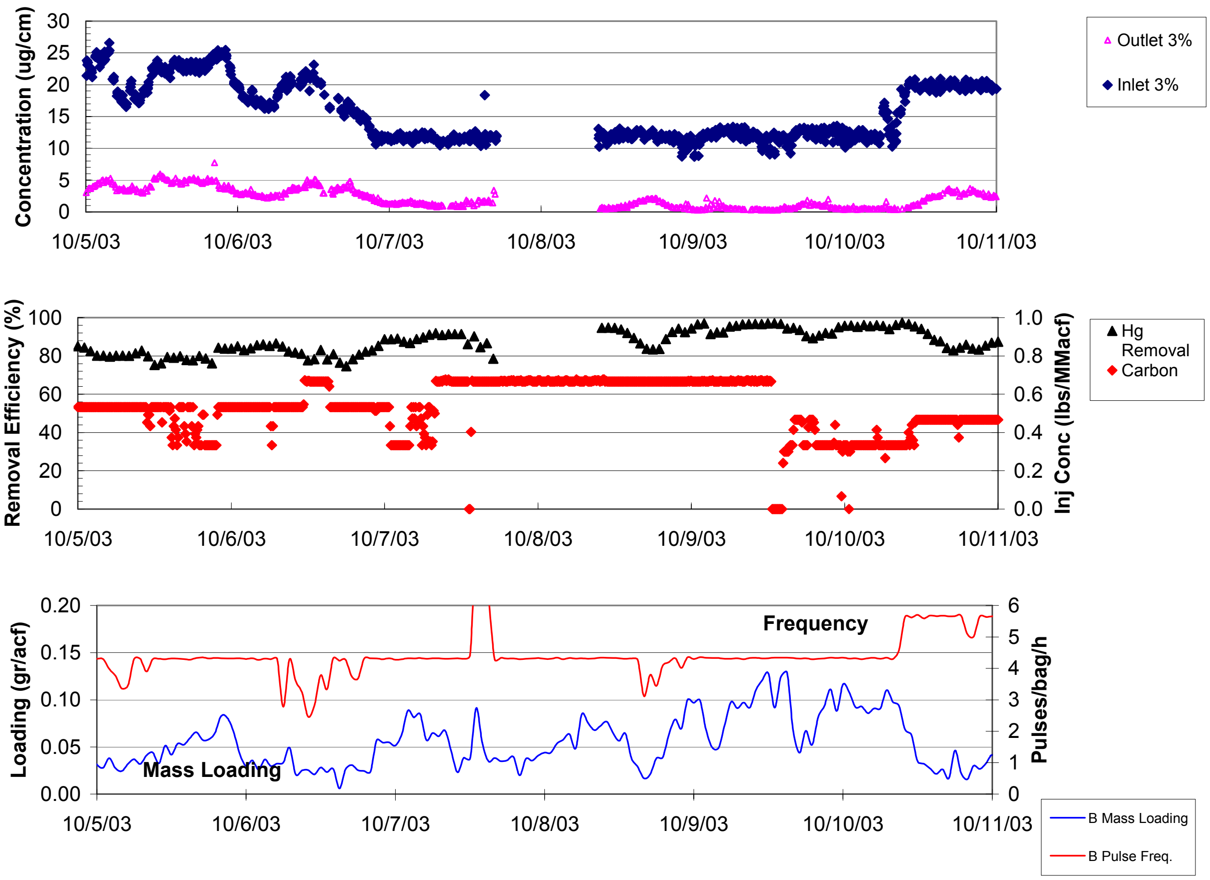

Figure 1. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC® cleaning frequency, and inlet mass loading on Unit 3 COHPAC® the week of Ontario Hydro tests, October 5 through 11, 2003.

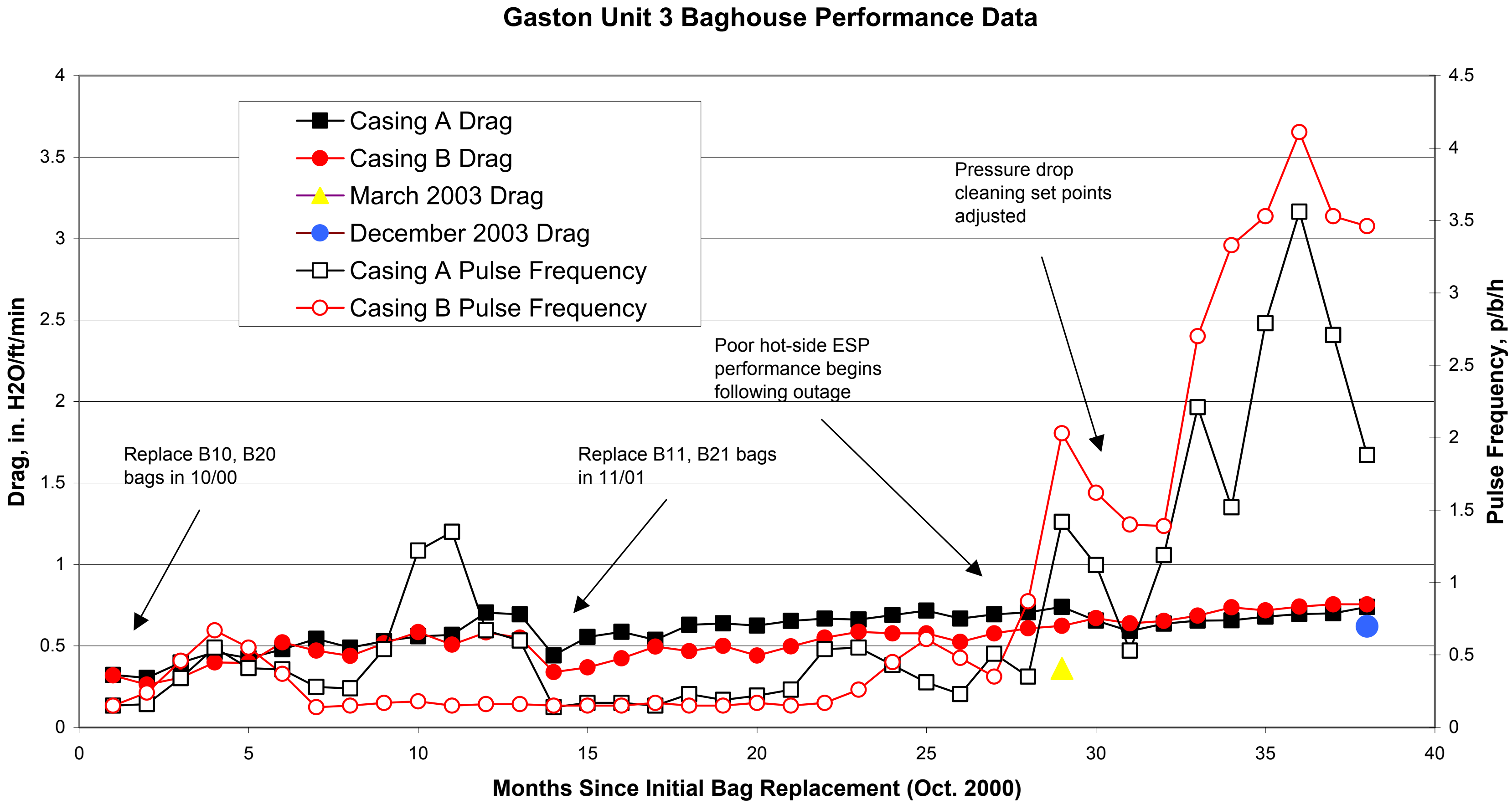

Figure 2. Gaston Unit 3 COHPAC® baghouse performance October 2000 through November 2003.

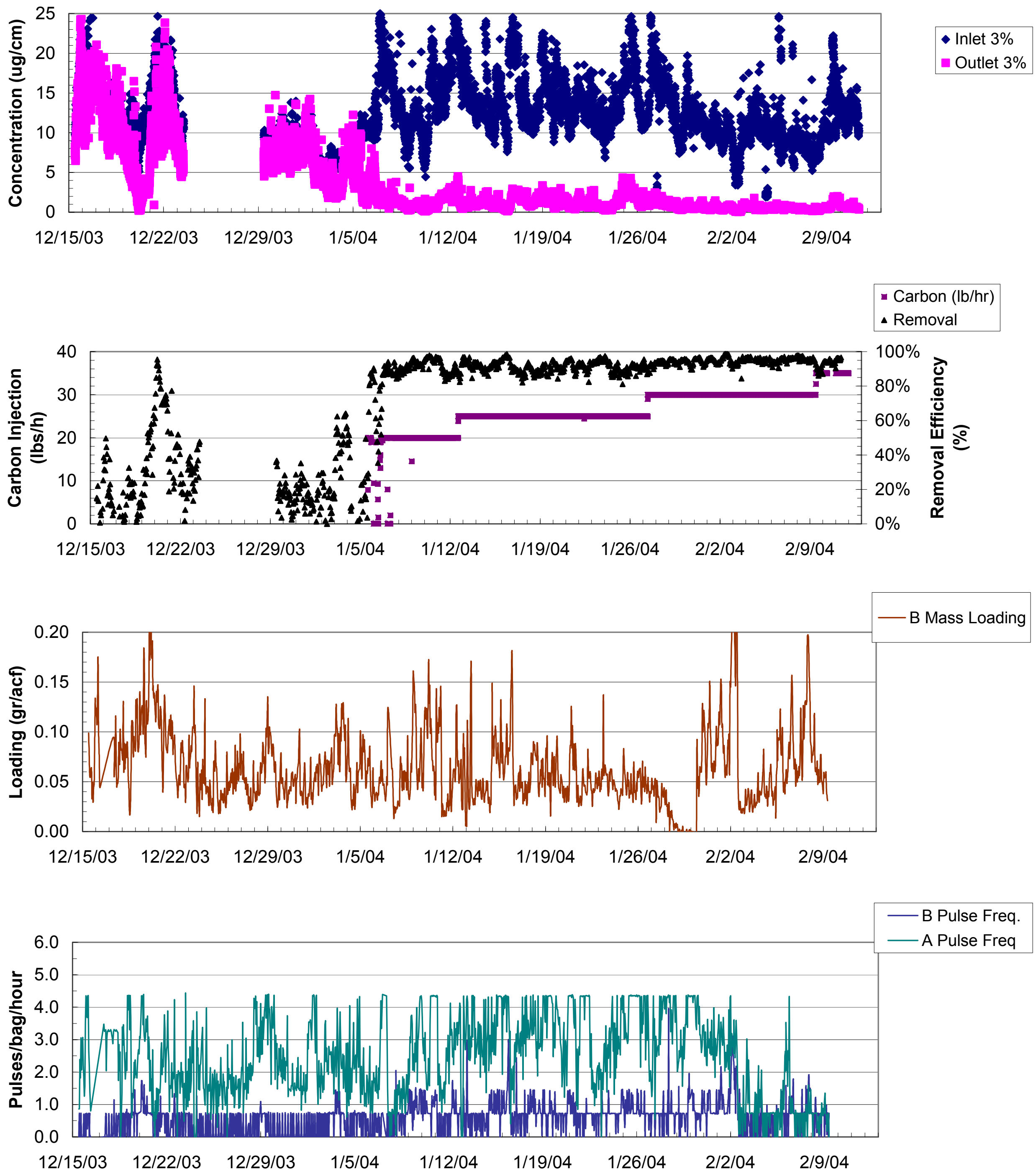

Figure 3. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC® cleaning frequency and inlet mass loading on Unit 3 COHPAC® from December 15, 2003, through February 11, 2004.